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Nobbe

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(54) **SYSTEMS AND METHODS FOR MINIMIZING INSERTION LOSS IN A MULTI-MODE COMMUNICATIONS SYSTEM**

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H04B 1/403 (2015.01)
H03H 7/01 (2006.01)

(52) **U.S. Cl.**
CPC ***H04B 1/406*** (2013.01); ***H03H 7/0161*** (2013.01); *H03H 2210/036* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

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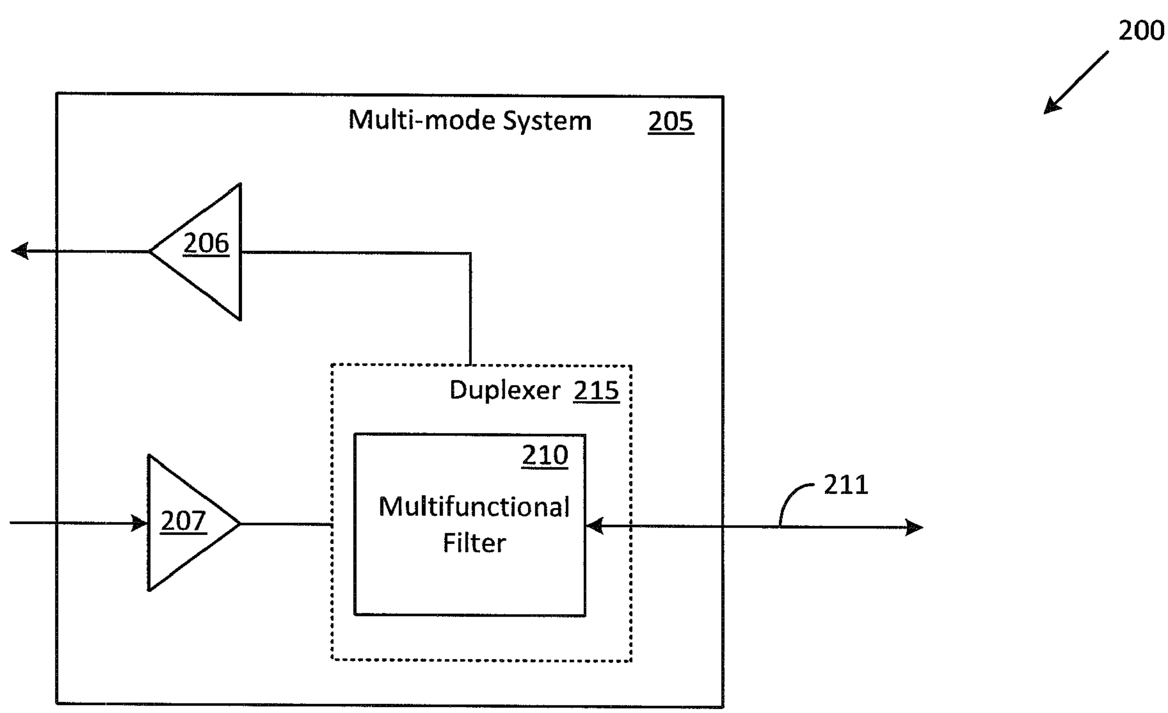
(57) **ABSTRACT**

Methods and system for using a multifunctional filter to minimize insertion loss in a multi-mode communications system are described. Specifically described is a multifunctional filter that is configurable to operate in a band-pass mode when a first type of signal is propagated through the multifunctional filter, and to operate in a low-pass mode when a second type of signal is propagated through the multifunctional filter. The multifunctional filter presents a lower insertion loss to the second type of signal when operating in the low-pass mode than in the band-pass mode.

23 Claims, 3 Drawing Sheets



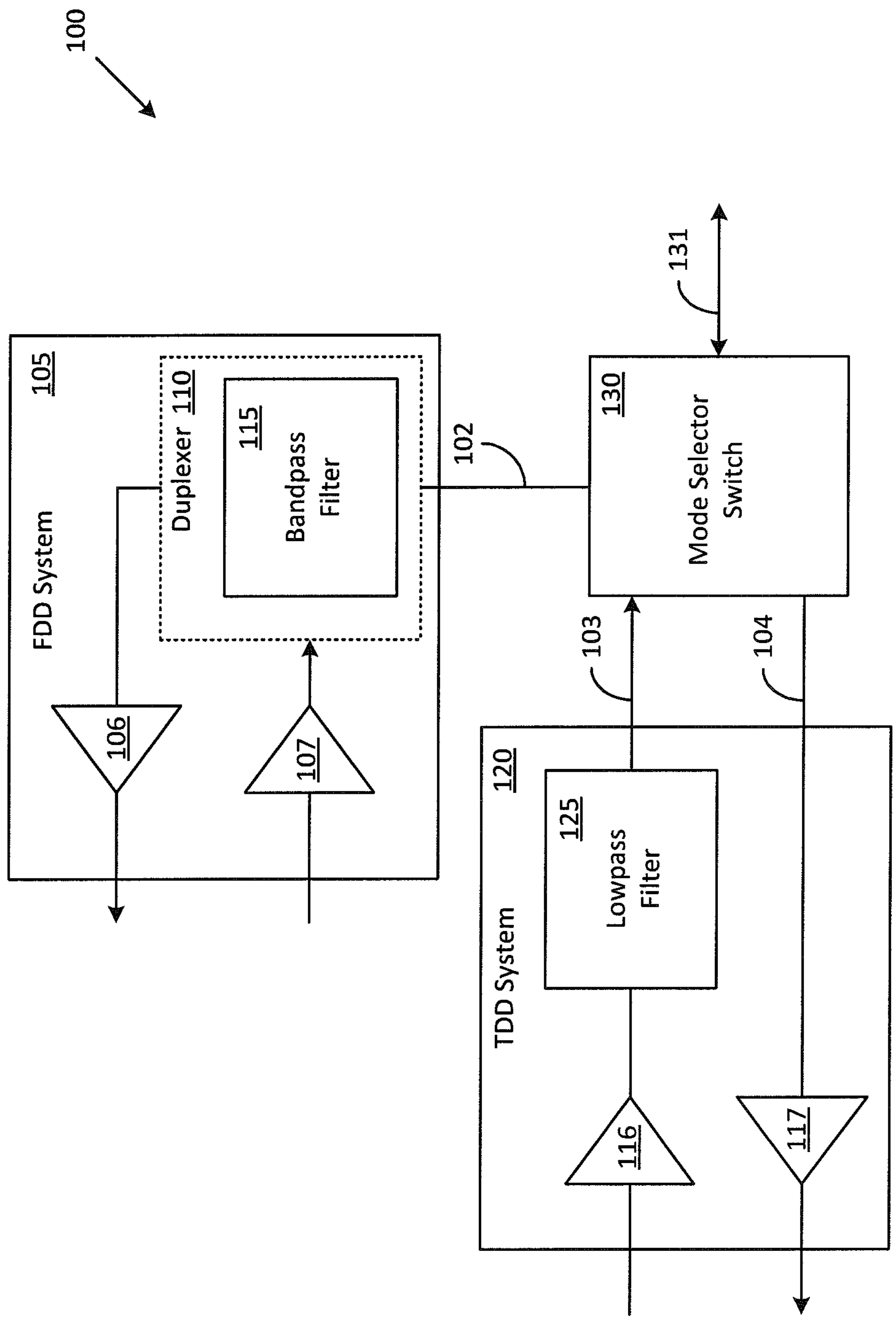


FIG. 1 (Prior art)

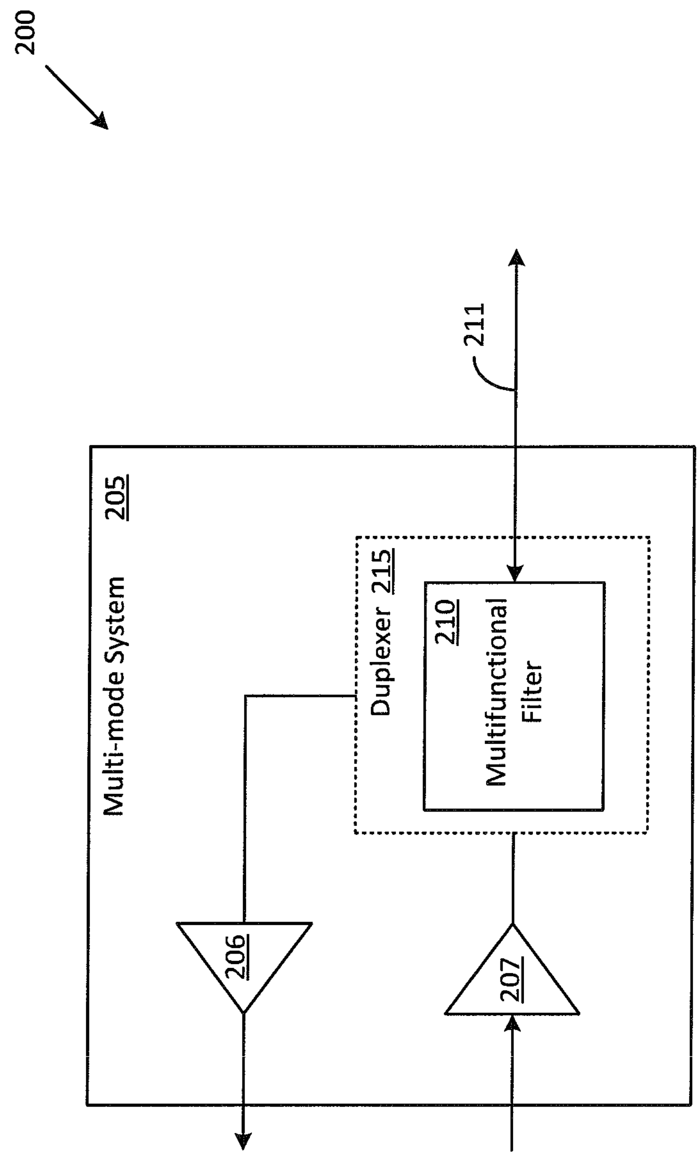

200
211
Multi-mode System
205
Duplexer 215
210
Multifunctional Filter
206
207

FIG. 2

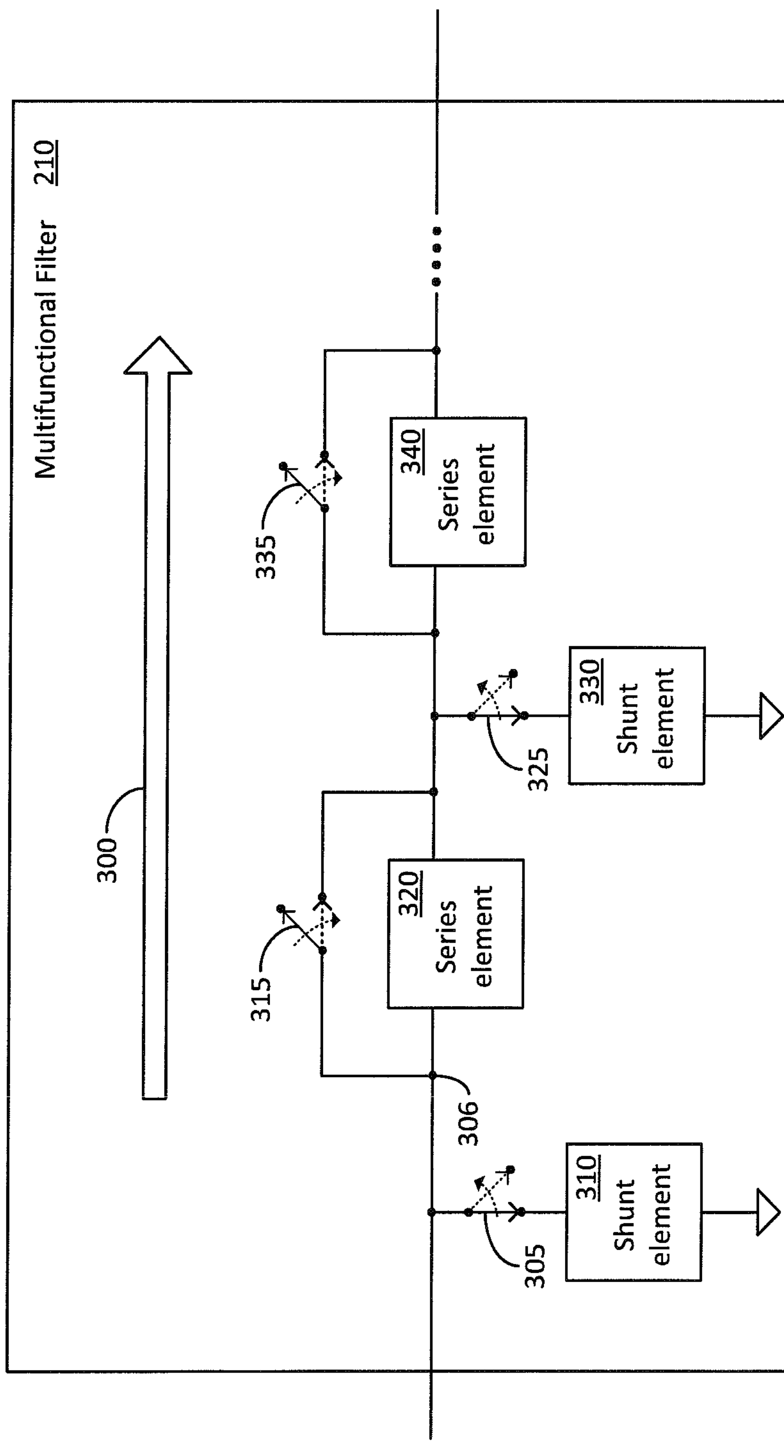

Multifunctional Filter 210
300
335
340
Series element
315
320
Series element
306
325
330
Shunt element
305
310
Shunt element

FIG. 3

SYSTEMS AND METHODS FOR MINIMIZING INSERTION LOSS IN A MULTI-MODE COMMUNICATIONS SYSTEM

FIELD

The present teachings relate to communications systems. In particular, the present teachings relate to using a multifunctional filter for minimizing insertion loss in a multi-mode communications system.

DESCRIPTION OF RELATED ART

Multi-band, multi-mode cellular phones are quite popular because of the convenience and flexibility provided by such devices, especially when a user of such a cellular phone travels between areas that are serviced by service providers using different signal propagation modes. Two of these signal propagation modes are referred to in the art as a time division duplex (TDD) mode and a frequency division duplex (FDD) mode.

A cellular phone that is configured to selectably operate in either the TDD mode or the FDD mode, typically incorporates a first set of circuit elements that is optimized for TDD mode of operation and a second set of circuit elements that is optimized for FDD mode of operation. A switching mechanism is employed to cut out one set of circuit elements and insert the other set of signal elements in a signal propagation path when it is desired to change the cellular phone from one mode of operation to the other.

FIG. **1** shows a prior art communications system **100** that incorporates two sets of circuit elements as mentioned above. The first set of circuit elements is contained in TDD system **120** that is optimized for TDD mode of operation while the second set of circuit elements is contained in FDD system **105** that is optimized for FDD mode of operation. A mode selector switch **130** is used for changing communications system **100** from one mode of operation to the other.

Signal line **131** couples mode selector switch **130** to an antenna (not shown) and carries communications signals in either FDD or TDD modes to/from the antenna. Specifically, a FDD signal is carried on signal line **131** when mode selector switch **130** is configured to couple FDD system **105** to signal line **131**. FDD system **105** includes a band-pass filter **115** that may be a standalone element or may be a part of a duplexer **110** (shown as a dashed box). Duplexer **110** permits duplex mode of operation wherein a transmit side signal can be coupled from transmit amplifier **107** into mode selector switch **130** while a receive side signal can be coupled from mode selector switch **130** into receiver **106**.

A TDD signal is carried on signal line **131** when mode selector switch **130** is configured to couple TDD system **120** to signal line **131**. TDD system **120** includes a low-pass filter **125**, a transmit amplifier **116**, and a receiver **117**. In carrying out a comparison between signal losses in the TDD mode of operation and the FDD mode of operation, it will be relevant to point out that the insertion loss imposed by low-pass filter **125** is lower than that imposed by band pass filter **115**.

Typically, the insertion loss of low-pass filter **125** is of the order of 0.5 dB whereas the insertion loss of band pass filter **115** is of the order of 2.5 dB. As can be understood, insertion loss plays a significant role in signal transmission. Consequently, the prior art configuration depicted in FIG. **1** provides for two separate circuits so as to minimize insertion loss when system **100** is operating in the TDD mode.

However, as can be understood, such a configuration can lead to various undesirable issues such as higher component count, higher production cost, bulkier packaging, and increased power consumption.

SUMMARY

According to a first aspect of the present disclosure, a method of minimizing insertion loss in at least one of two types of signals propagated through a communications system is provided. The method includes configuring a multifunctional filter to operate in a band-pass mode when a first type of signal is propagated through the multifunctional filter, and reconfiguring the multifunctional filter to operate in a low-pass mode when a second type of signal is propagated through the multifunctional filter, the low-pass mode providing a lower insertion loss upon the second type of signal than the band-pass mode.

According to a second aspect of the disclosure, a method of minimizing insertion loss in a duplexer is provided. The method includes configuring the duplexer to operate in a band-pass mode when a first type of signal is propagated through the duplexer, and reconfiguring the duplexer to operate in a low-pass mode when a second type of signal is propagated through the duplexer, the low-pass mode providing a lower insertion loss upon the second type of signal than the band-pass mode.

According to a third aspect of the disclosure, a communications system is provided. The system includes a multifunctional filter that is configurable to operate in a band-pass mode when a first type of signal is propagated through the multifunctional filter, and to operate in a low-pass mode when a second type of signal is propagated through the multifunctional filter, the low-pass mode providing a lower insertion loss to the second type of signal than the band-pass mode.

Further aspects of the disclosure are shown in the specification, drawings and claims of the present application.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the present disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily drawn to scale. Instead, emphasis is placed upon clearly illustrating various principles. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** shows a prior art communications system that uses two separate sets of circuit elements for selectably operating the communications system in either a TDD mode or a FDD mode.

FIG. **2** shows a communications system incorporating a multifunctional filter that can be selectively configured for operating the communications system in either a TDD mode or a FDD mode.

FIG. **3** shows a few components that may be contained in the multifunctional filter shown in FIG. **2**.

DETAILED DESCRIPTION

Throughout this description, embodiments and variations are described for the purpose of illustrating uses and implementations of the inventive concept. The illustrative description should be understood as presenting examples of the inventive concept, rather than as limiting the scope of the concept as disclosed herein. For example, it will be understood that terminology such as multi-functional, multi-mode, nodes, terminals, voltage drops, circuits, blocks, connections, lines, and coupling are used herein as a matter of convenience for description purposes and should not be interpreted literally in a narrow sense. Furthermore, the words "block" or "functional blocks" as used herein refer not only to a circuit containing discrete components or integrated circuits (ICs), but may also refer to various other elements such as a module, a sub-module, or a mechanical assembly. Similarly, the word "line" as used herein may refer to various connectivity elements such as a wire, a cable, a copper track on a printed circuit board, an optical fiber, or a wireless link. Also, it must be understood that the word "example" as used herein (in whatever context) is intended to be non-exclusionary and non-limiting in nature. It will be further understood that labels such as "band-pass" and "notch" filter are used herein solely for purposes of description. Consequently, other labels and other filtering functionalities are included in the scope of the concept disclosed herein. A person of ordinary skill in the art will understand the principles described herein and recognize that these principles can be applied to a wide variety of applications using a wide variety of physical elements.

In particular, described herein are some systems and methods pertaining to using a multifunctional filter for minimizing insertion loss in a multi-mode communications system. As can be understood by one of ordinary skill in the art, the described systems and methods can be incorporated into a wide variety of communications systems, and furthermore such communications systems may be used in a variety of devices and applications spanning a variety of operating conditions (frequencies, voltages, power etc).

FIG. **2** shows a communications system **200** having a multi-mode system **205** incorporating a multifunctional filter **210** that can be selectively configured for operating communications system **200** in either a TDD mode or a FDD mode. It will be understood that multifunctional filter **210** may be referred to alternatively as a dual-purpose filter, an integrated filter, or a combination filter. Persons of ordinary skill in the art can recognize the equivalency amongst such alternative labels.

It will also be understood that communications system **200** includes several other elements (in addition to multi-mode system **205**), which are not shown in FIG. **2**. These other elements have been omitted so as to avoid obscuring the primary focus of this disclosure.

Multi-mode system **205** further includes a wide band transmit amplifier **207** and a wide band receiver **117**, each of which is selected to have a bandwidth, as well as other characteristics that accommodate both FDD and TDD modes of signal propagation. In a first embodiment, multifunctional filter **210** is a standalone component that may be placed in either a transmit signal propagation path or a receive signal propagation path. In another embodiment, multifunctional filter **210** is a part of a duplexer **215** that is shown as a dashed box in FIG. **2**. Duplexer **215** couples any signal that is received on line **211** from an antenna (not shown) and routes this received signal to wide band receiver **117**. Duplexer **215** further couples transmit-side signals from wide band transmit amplifier **207** into line **211** through which the transmit-side signals are coupled to the antenna. As can be understood, transmit-side signals are generally much stronger in signal amplitude than the received-side signals. Duplexer **215** prevents a large part, or all of, this stronger transmit-side signal from reaching wide band receiver **206** and causing damage to receiver **206**, which is designed to receive low amplitude signals and therefore, contains circuitry susceptible to overload damage.

As mentioned above, multifunctional filter **210** can be selectively configured in accordance with communications system **200** operating in either a TDD mode or a FDD mode. Specifically, multifunctional filter **210** is configurable as a band-pass filter when communications system **200** is placed in an FDD mode of operation. Conversely, multifunctional filter **210** is configurable as a low-pass filter when communications system **200** is placed in a TDD mode of operation. The low-pass filter configuration imposes a lower insertion loss upon a TDD signal than that imposed by the band-pass filter (if such a band-pass filter were permitted to be located in a signal propagation path of the TDD signal).

In various other embodiments, multifunctional filter **210** can be selectively configured in accordance with multi-mode system **205** operating in modes other than a TDD mode or a FDD mode. For example, in a first of other such operational modes, multifunctional filter **210** may be configurable to perform a first filtering function (such as, for example, low pass, high pass, band-pass, single notch, multiple notches, single band-stop, multi-band stop etc) and then re-configurable in a second operational mode to perform a second different filtering function. It can be understood that the first filtering function may be more suitable for the first operational mode but may not be optimal for the second operational mode (for example, as a result of having a higher insertion loss, or some other such undesirable characteristic).

Attention is now drawn to FIG. **3**, which shows certain elements contained inside multifunctional filter **210**. The configuration shown is a generic ladder network solely for purpose of description, and it will be understood that various combinations and arrangements of series and shunt elements (capacitors, inductors, resistors etc in π and/or T-configurations) may be used in various alternative embodiments. Furthermore, it will be noticed that only two filter stages are shown in FIG. **3**, with each stage having one shunt element and one series element. However, a single stage or more than two stages ('n' stages) may be employed in various other embodiments, furthermore with more than one element located in each shunt and/or series limb if so desired.

Switch **305**, which may be a normally-closed switch, is controllable via a control signal (not shown) that may be used to place switch **305** in an open position when it is desired to isolate shunt element **310** from signal propagation path **300**. Switch **315**, which may be a normally-open switch, is also provided a control signal (not shown) that may be used to place switch **315** in a closed position, thereby providing a low impedance shunt signal path that effectively eliminates series element **320** from signal propagation path **300**, when so desired. Switches **325** and **335** may be operated in a similar manner for configuring shunt element **330** and series element **340** respectively.

In one implementation, each of shunt elements **310** and **330** is a capacitor (C), while each of series elements **320** and **340** is an inductor (L). When all of these elements (having appropriately selected values) are included in signal propagation path **300**, multifunctional filter **210** operates as a band-pass filter. On the other hand, when some of these elements, for example, shunt element **310** and series element **340** are switched out of signal propagation path **300**, multifunctional filter **210** operates as an L-C low-pass filter.

Thus, by suitably operating one or more of switches **305**, **315**, **325** and **335**, multifunctional filter **210** can be configured as a single stage or a multi-stage filter having either a band-pass or a low-pass characteristic. The overall impedance characteristics of multifunctional filter **210** can be configured to any suitable value by not only operating one or more of switches **305**, **315**, **325** and **335** so as to insert or remove one or more filter stages, but also by inserting resistors in lieu of, or to complement, one or more of shunt element **310**, shunt element **330**, series element **320** and series elements **340**.

When configured as a band-pass filter, multifunctional filter **210** may be used to selectively attenuate certain frequencies, such as undesirable harmonics or transmit-side frequencies that may cause damage to receiver **206** (FIG. **2**).

Each of switches **305**, **315**, **325** and **335** may be implemented in several alternative ways. A non-exhaustive list of devices that may be used include relays, solid-state switches, discrete switching semiconductors (such as field effect transistors), micro-electro mechanical systems (MEMS), and controllable variable impedance devices. A few examples of controllable variable impedance devices include a varicap, a varactor, a varistor, a thyristor, and a barium strontium titanate (BST) capacitor.

Such devices may be configured to not only operate as switches (with a high impedance constituting an open switch condition and a low impedance constituting a closed switch condition), but may also, in some embodiments, be used as impedance modification devices. For example, when switch **315** is a variable inductor, the value of the inductance provided by switch **315** may be varied under suitable voltage control to provide a desired inductance value that operates in parallel with the inductance value provided by series element **320**. In another example, when switch **315** is a variable capacitor, the value of the capacitance provided by switch **315** may be varied under suitable voltage control so as to provide a desired capacitance value that operates in parallel with the inductance value provided by series element **320**. Such a combination may be used as part of a tuned circuit for selectively propagating certain frequencies while blocking certain other frequencies in the signal propagation path **300**. In yet another example, switch **315** is provided in the form of multiple elements, for example, a resistor in parallel (or in series) with an inductor or a capacitor. Such combinations may be used for example to obtain specific Q values in a tuned circuit formed in conjunction with series element **320**.

The other switches shown in FIG. **3** may be also configured in similar ways. Furthermore, though not shown, it will be understood that additional switches may be located in various other limbs of multifunctional filter **210**. For example, an additional switch may be located on the limb connecting junction **306** to series element **320**. This additional switch may be operated in conjunction with switch **315**. Thus, when switch **315** is closed, the additional switch may be opened so as to isolate the input side of series element **320** and reduce signal loss in series element **320**, or to present a higher impedance value in parallel with closed switch **315**.

The person skilled in the art will appreciate that the systems, components, and methods described herein allow for using a multifunctional filter to minimize insertion loss in a multi-mode communications system. While the devices and methods have been described by means of specific embodiments and applications thereof, it is understood that numerous modifications and variations could be made thereto by those skilled in the art without departing from the spirit and scope of the disclosure. It is therefore to be understood that, within the scope of the claims, the disclosure may be practiced otherwise than as specifically described herein.

A number of embodiments of the present inventive concept have been described. Nevertheless, it will be understood that various modifications may be made without departing from the scope of the inventive teachings.

Accordingly, it is to be understood that the inventive concept is not to be limited by the specific illustrated embodiments, but only by the scope of the appended claims. The description may provide examples of similar features as are recited in the claims, but it should not be assumed that such similar features are identical to those in the claims unless such identity is essential to comprehend the scope of the claim. In some instances the intended distinction between claim features and description features is underscored by using slightly different terminology.

What is claimed is:

1. A method of minimizing insertion loss in at least one of two types of signals propagated through a communications system, the method comprising:

configuring a configurable combination filter to operate in a band-pass mode when a first type of signal is propagated through the combination filter, the combination filter comprising a plurality of independently selectable serial filter components, a plurality of independently selectable shunt filter components, a plurality of parallel switches connected in parallel with the plurality of independently selectable serial filter components and a plurality of serial switches connected in serial with the plurality of independently selectable shunt filter components, and wherein configuring the combination filter to operate in the band-pass mode comprises providing a first propagation path of the first type of signal by including the plurality of independently selectable serial and shunt filter components in the first propagation path, wherein the including comprises placing the plurality of parallel switches in an open position such that no serial switch is present in the first propagation paths and placing the plurality of serial switches in a closed position; and

configuring the combination filter to operate in a low-pass mode when a second type of signal is propagated through the combination filter, wherein configuring the combination filter to operate in the low-pass mode comprises providing a second propagation path of the second type of signal by removing at least one filter component of the plurality of independently selectable serial and shunt filter components from the second propagation path by placing a corresponding parallel switch of the plurality of parallel switches in a closed position or by placing a corresponding serial switch of the plurality of serial switches in an open position, the low-pass mode providing a lower insertion loss upon the second type of signal than the band-pass mode.

2. The method of claim **1**, wherein the first type of signal is a frequency division duplex signal and the second type of signal is a time division duplex signal.

3. The method of claim **2**, wherein the combination filter is a part of a duplexer unit that accommodates duplex signal transmission in the communications system.

4. The method of claim **3**, further comprising:

configuring the combination filter to provide a notch-type attenuation upon at least one harmonic component of the time division duplex signal.

5. The method of claim **3**, wherein the second propagation path is a receive signal path in the duplexer unit.

6. The method of claim **5**, wherein removing the at least one filter component from the signal propagation path comprises placing the plurality of parallel switches in a closed position and placing the plurality of serial switches in an open position.

7. The method of claim **1**, wherein the plurality of independently selectable serial filter components are inductors and the plurality of independently selectable shunt filter components are capacitors.

8. A method of minimizing insertion loss in a duplexer, the method comprising:

configuring the duplexer to operate in a band-pass mode when a first type of signal is propagated through the duplexer; and

configuring the duplexer to operate in a low-pass mode when a second type of signal is propagated through the duplexer, the low-pass mode providing a lower insertion loss upon the second type of signal than the band-pass mode,

wherein configuring the duplexer to operate in one of the band-pass or low-pass modes comprises configuring a multifunctional filter contained in the duplexer to operate in one of the band-pass or low-pass modes.

9. The method of claim **8**, wherein the first type of signal is a frequency division duplex signal, the second type of signal is a time division duplex signal,

wherein the multifunctional filter comprises:

a plurality of independently selectable serial filter components, a plurality of independently selectable shunt filter components, a plurality of parallel switches connected in parallel with the plurality of independently selectable serial filter components and a plurality of serial switches connected in serial with the plurality of independently selectable shunt filter components,

wherein configuring the combination filter to operate in the band-pass mode comprises providing a first propagation path of the first type of signal by including the plurality of independently selectable serial and shunt filter components in the first propagation path, wherein the including comprises placing the plurality of parallel switches in an open position such that no serial switch is present in the first propagation paths and placing the plurality of serial switches in a closed position, and

wherein configuring the combination filter to operate in the low-pass mode comprises providing a second propagation path of the second type of signal by removing at least one filter component of the plurality of independently selectable serial and shunt filter components from the second propagation path by placing a corresponding parallel switch of the plurality of parallel switches in a closed position or by placing a corresponding serial switch of the plurality of serial switches in an open position.

10. The method of claim **9**, further comprising:

configuring the multifunctional filter to provide a notch-type attenuation upon at least one harmonic component of the time division duplex signal.

11. The method of claim **9**, wherein the first type of signal is a frequency division duplex signal, the second type of signal is a time division duplex signal.

12. The method of claim **11**, further comprising coupling the duplexer to a receiver unit, and wherein the signal propagation path is a receive signal path configured to direct a signal received at the duplexer into the receiver.

13. The method of claim **12**, wherein removing the at least one filter component from the receive signal path comprises placing the plurality of parallel switches of the multifunctional filter in a closed position and placing the plurality of serial switches of the configurable combination filter in an open position.

14. A communications system comprising:

a multifunctional filter comprising a plurality of independently selectable serial filter components, a plurality of independently selectable shunt filter components, a plurality of parallel switches connected in parallel with the plurality of independently selectable serial filter components and a plurality of serial switches connected in serial with the plurality of independently selectable shunt filter components,

wherein the multifunctional filter is configurable to operate in a band-pass mode when the plurality of parallel switches are placed in an open position and the plurality of serial switched are placed in a closed position for propagation of a first type of signal through the multifunctional filter, and

to operate in a low-pass mode when at least one of the plurality of parallel switches is placed in a closed position or at least one of the plurality of serial switches is placed in an open position for propagation of a second type of signal through the multifunctional filter,

the multifunctional filter presenting a lower insertion loss to the second type of signal when operating in the low-pass mode than in the band-pass mode.

15. The system of claim **14**, wherein the first type of signal is a frequency division duplex signal and the second type of signal is a time division duplex signal.

16. The system of claim **15**, wherein the multifunctional filter is a part of a duplexer unit contained inside a multi-mode cellular phone that is selectively operable in a frequency division duplex mode or a time division duplex mode.

17. The system of claim **16**, wherein the multifunctional filter further comprises an input/output terminal connected to an antenna for receive and transmit of the first and the second type of signals.

18. The system of claim **17**, wherein the multifunctional filter is configured to provide a signal path for receive/transmit of the first signal type through the antenna devoid of series connected switches.

19. The System of claim **16**, wherein the duplexer unit is connected to a single wide band receive amplifier and a single wide band transmit amplifier to respectively receive and transmit the first and second type signals.

20. The system of claim **14**, wherein the multifunctional filter comprises multiple filter stages and at least one of the multiple filter stages is selectively eliminated when the second type of signal is propagated through the multifunctional filter.

21. The system of claim **20**, further comprising a receiver, and wherein the at least one of the multiple filter stages is selectively eliminated in a receive signal path through which a signal is routed to the receiver.

22. The system of claim **14**, further comprising a signal detection circuit configured to detect the presence of one of the first or the second type of signal and automatically configure the multifunctional filter to operate in the band-pass mode or the low-pass mode respectively.

23. The system of claim **14**, further comprising at least one variable impedance device for further configuring the multifunctional filter to operate in one of the band-pass mode or the low-pass mode.

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